Metal template effect on *O*-alkylation of tetrathiacalix[4]arene with 2-bromoacetamide to afford tetrakis(carbamoylmethoxy)thiacalix [4]arenes with *cone* and 1,3-*alternate* conformation

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Direct *O*-alkylation of tetrathiacalix[4]arene with 2-bromoacetamide afforded two conformational isomers (*cone* and 1,3-*alternate*) of tetrakis(carbamoylmethoxy)thiacalix[4]arene and 1,3-disubstituted bis(carbamoylmethoxy)thiacalix [4]arene, depending on the base used.

Keywords: thiacalix[4]arene, *O*-alkylation, template effect, conformation, intramolecular hydrogen bond

Since the thiacalix[4]arene **1** is easily accessible[1] an increasing interest on its novel properties has made this new member of the calixarene familiy[2–7] popular as a building block or molecular scaffolds. It is well known that conformation selective tetra-*O*-alkylation at the lower rim of all kinds of calixarenes is controlled by choosing a suitable alkali carbonate as a base.[8,9] In principle, the introduction of bulkier groups to the lower rim of calix[4]arene leads to the formation of four stable isomers–*cone*, *partial-cone*, 1,2-*alternate* and 1,3-*alternate*. In the case of thiacalix[4]arene, the same conformational isomers are possible, however, their conformational behaviour differs to a high degree from that of the classical calix[4]arene due to the presence of the sulfur atoms instead of the CH_2 groups. Previously, Lhoták *et al*.[10] has reported that tetra-*O*-alkylation of thiacalix[4]arene with simple alkyl halides leads to the 1,3-*alternate* conformer as a major products. Iki *et al*.[9] have studied the preparation and ionophoric properties of the four conformers of tetra-*tert*-butyltetrakis[(ethoxycarbonyl) methoxy]thiacalix[4]arene. Previously, we reported[11] conformational studies of tetrakis[(2-pyridylmethyl)oxy] tetrathiacalix[4]arenes constraining *cone* and 1,2-*alternate* conformation. On the other hand, several groups have demonstrated that calix[4]aryl ester and amide derivatives serve as neutral ionophores.[12–14] In particular, the complexation behaviour of calix[4]arene amide derivatives have been extensively investigated due to their higher ionophoric ability to bind to alkali ion, transition ions, lanthanide ions and oxyanions than that of the ester derivatives.[15,16] Note that the binding ability of amide functional group with either hard or soft cations provides entries to higher form of molecular behaviour such as cooperativity, allostery and regulation. It is well-known that the complexation behaviour of all the calixarene family depends on the conformation of their derivatives. Recently, Lamartine *et al*.[17] reported a thiacalix[4]arene tetraamide derivative synthesised by applying the procedures established for calix[4]arene. Despite the obvious importance of thiacalix[4]arenes amide derivatives no conformational studies of the direct tetra-*O*-alkylation of **1** with primary amides have been reported so far.

We now describe the metal template effect on *O*-alkylation of tetrathiacalix[4]arene with 2-bromoacetamide in the presence of different bases to afford tetrakis(carbamoylmethoxy)thiacalix[4]arenes with cone- and 1,3-alternate conformation and their conformational studies in solution.

Results and discussion

Like calix[4]arene, complete *O*-alkylation of the OH groups of tetrathiacalix[4]arene may produce all the four possible isomers at most, each of which should be conformationally stable in the cone, 1,2-alternate, partial-cone, and 1,3-alternate conformations. Conformational studies, namely of tetraester derivatives of **1**, indicate that the cone conformer is obtained quite selectively in the presence of Na_2CO_3, the partial-cone and 1,3-*alternate* conformers are obtained by using K_2CO_3 and Cs_2CO_3, respectively.[8,9] Consequently, similar conformational preference for the *O*-alkylation of **1** with 2-bromoacetamide could be expected. Alkylation of the flexible macrocycle **1** with 2 mol equiv. of 2-bromoacetamide in the presence of Na_2CO_3 under acetone reflux gave one pure regioselective isomer, 1,3-di-*O*-substitution product *distal*-**3** as a major product, while other possible isomers were not observed. Increased the amount of reagent to 10 mol equiv. furnished to complete *O*-substitution, affording tetrakis(carbamoyl-methoxy) derivative *cone*-**4** in quantitative yield. No formation of other possible conformers has been observed. Only when the template metal can hold the carbamoylmethoxy group(s) and the oxide group(s) on the same side of the thiacalixarene **1** the conformation is immobilised to the cone. The template effect of the sodium cation plays an important role in this alkylation reaction. However, in the case of NaH under THF reflux only the recovery of the starting compound **1** resulted in spite of the condition of large excess of NaH and alkylating reagent.

In contrast, similar reaction was carried out in the presence of K_2CO_3 to yield a one pure isomer, 1,3-*alternate*-tetra-*O*-alkylated product 1,3-*alternate*-**4** in 80% yield. Similarly, when Cs_2CO_3 is employed for *O*-alkylation with 2-bromoacetamide only 1,3-*alternate*-**4** was also obtained in 85% yield. The formation of the other possible isomers was not observed. Thus, much higher metal template effect on *O*-alkylation of *p*-*tert*-butyltetrathiacalix[4]arene **1** with 2-bromoacetamide than those of *O*-alkylation with ethyl bromoacetate[9,18] or *N*,*N*-diethylchloracetamide.[19,20] These results indicate that when 2-bromoacetamide is used in the presence of K_2CO_3 or Cs_2CO_3, not only the undissociated OH group forms intramolecular hydrogen bonds with the dissociated O^- group, which weakens the metal template effect arising from the M^+---O^- interaction but also the larger K^+ or Cs^+ might enlarge the thiacalixarene ring of tetraol **1** to form a sufficient space for ring inversion to afford the 1,3-alternate conformer.

The ^{1}H NMR spectrum of *cone*-**4** shows a singlet for the *tert*-butyl protons at δ 1.13 ppm and a singlet for the aromatic protons at δ 7.43 ppm. Furthermore, the resonance for the ArOCH_2CONH$_2$ methylene protons appeared as a singlet at δ 4.68 ppm. Similarly, the ^{1}H NMR spectrum of 1,3-*alternate*-**4** shows a singlet for the *tert*-butyl protons at δ 1.26 ppm, a singlet for the ArOCH_2CONH$_2$ methylene protons at δ 4.50 ppm, and a singlet for the aromatic protons at δ 7.40 ppm. These signals correspond to a symmetric structure (C_2-symmetry).

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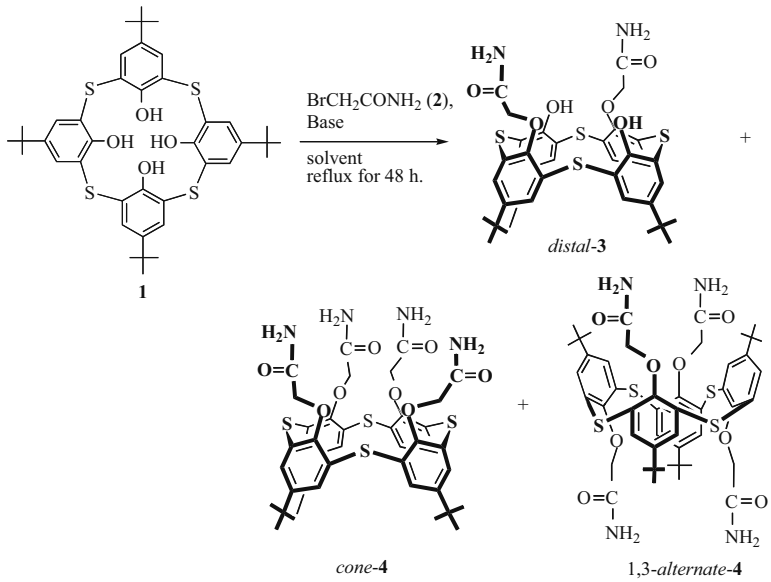


Scheme 1

Table 1 *O*-Substitution reaction of tetraol **1** with 2-bromoacetamide **2**

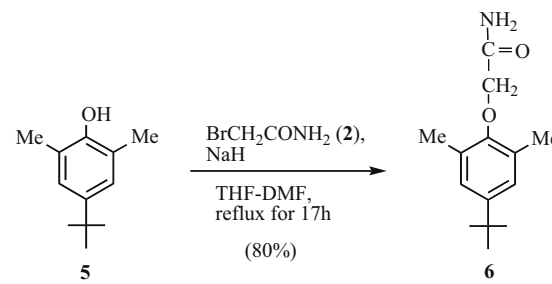
Run	Base	Solvent	**2**/**1** [mol/mol]	Yield/%[a,b] 1,3-*alternate*	Yield/%[a,b] *cone*	*O*-Substitution
1	Na_2CO_3	Acetone	2	0	0	Di[c]
2	Na_2CO_3	Acetone	10	0	100 [80]	Tetra
3	K_2CO_3	Acetone	10	100 [80]	0	Tetra
4	Cs_2CO_3	Acetone	10	100 [85]	0	Tetra
5	NaH[d]	THF	10	0	0	–

[a]The yield determined by ^{1}H NMR. [b]Isolated yields of tetra-*O*-substitution product **4** are shown in square parentheses.
[c]1,3-Di-*O*-substitution product *distal*-**3** was obtained in 80% yield. [d]The starting compound **1** was recovered in quantitative yield.

These conformers exhibit distinct differences in their ^{1}H NMR spectra. Therefore, based on the chemical shift of the C(CH_3)$_3$, CH_2CON and Ar*H* protons in the ^{1}H NMR spectra the two conformers of **4** were reasonably assigned to *cone* and 1,3-*alternate*. Thus, the peak of OCH_2CON protons at δ 4.68 and 4.50 ppm were assigned to *cone* and 1,3-*alternate* conformers, respectively; the latter one was folded into the π-cavity formed by the inverted benzene rings and thus shifted stronger upfield.[9,21–23]

Several examples of the formation of intramolecular hydrogen-bonding among opposing urea groups which can bind anionic species in calix[4]arenes have been reported.[24–26] Therefore, intramolecular hydrogen bonding may be foreseen between the NH and CO groups. In order to investigate the existence of intramolecular hydrogen bonding in **4** the reference compound **6** was synthesised in 80% yield by *O*-alkylation of **5**[27] with 2-bromoacetamide in the presence of NaH as a base under THF–DMF reflux for 17 h.

The chemical shifts of the N*H* protons and the differences (Δδ) in the chemical shifts of **4** from that of the reference compound **6** in $CDCl_3$ are shown in Table 2. Compared with the chemical shift of the NH_a protons of **6** (δ 5.54 ppm) the corresponding chemical shift at δ 7.69 ppm arising from the formation of intramolecular hydrogen bonding in *cone*-**4** shows a downfield (Δδ = –2.15 ppm). The strong intramolecular



Scheme 2

Table 2 Chemical shifts (δ) of the N*H* protons of *distal*-**3**, *cone*-**4**, 1,3-*alternate*-**4** and reference compound **6**[a]

Compound	δ_{NHa}($\Delta\delta_{ref.NHa}$[b])	δ_{NHb} ($\Delta\delta_{ref.NHb}$[b])	$\Delta\delta_{NH}$[c]
distal-**3**	5.88 (–0.34)	8.55 (–2.50)	–2.67
cone-**4**	7.69 (–2.15)	7.83 (–1.78)	–0.14
1,3-alternate-**4**	5.18 (+0.36)	5.23 (+0.82)	–0.05
Reference **6**	5.54 –	6.05 –	–0.51

[a]Determined in $CDCl_3$ by using $SiMe_4$ as a reference and express δ in ppm; [b]$\Delta\delta_{ref.}$ = δ [reference **6**] – δ [thiacalixarene];
[c]$\Delta\delta_{NH}$ = δ_{NHa} – δ_{NHb}

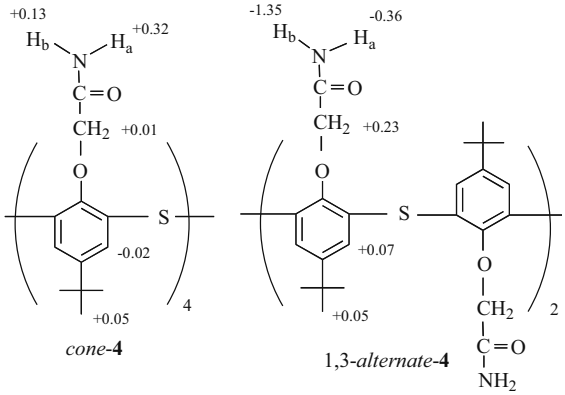


Fig. 1 Chemical shifts changes of *cone*-**4** and 1,3-*alternate*-**4** in $CDCl_3$ and DMSO-d_6. $\Delta\delta_{sol.}$ = δ [in $CDCl_3$] – δ [in DMSO-d_6].

hydrogen bonding between N*H*$_a$ and CO groups implies a close contact of the chains OCH_2CONH_a due to the cone-conformation. These downfield shifts are conspicuous due to several examples of the formation of intramolecular hydrogen bonding in calix[4]arene constraining cone conformation are well known. In contrast, the N*H*$_a$ protons of 1,3-*alternate*-**4**, constraining 1,3-*alternate* conformation, shows an upfield (*i.e.* Δδ = + 0.36 ppm). This might suggest the steric hindrance of the *tert*-butyl groups avoid the formation of intramolecular hydrogen bonding between the distal positions. Similar tendency of chemical shift of N*H*$_b$ protons was observed in both *cone*-**4** and 1,3-*alternate*-**4**.

^{1}H NMR dilution studies showed no change of the chemical shifts of both N*H*$_a$ and N*H*$_b$ protons due to the concentration-independent intramolecular hydrogen-bonding in *cone*-**4**. Due to the N*H* groups can also form intermolecular hydrogen-bonding based on the solvent, the compound *cone*-**4** was dissolved in the strongly hydrogen-bonding solvent DMSO-d_6. The both upfield shifts of N*H*$_a$ and N*H*$_b$ protons of *cone*-**4** at δ 7.37 and 7.70 ppm (*i.e.* $\Delta\delta_{sol.}$ = + 0.32 ppm for N*H*$_a$, $\Delta\delta_{sol.}$ = + 0.13 ppm for N*H*$_b$) also indicate the formation of much stronger intramolecular hydrogen-bonding network between N*H* and CO groups than that in 1,3-*alternate*-**4**. By contrast, downfield shifts of N*H*$_a$ and N*H*$_b$ protons of 1,3-*alternate*-**4** at δ 5.54 and 6.58 ppm (*i.e.* $\Delta\delta_{sol.}$ = –0.36 ppm for N*H*$_a$, $\Delta\delta_{sol.}$ = –1.35 ppm for N*H*$_b$) different from the upfield shifts of *cone*-**4** were observed, apparently from the weaker intramolecular hydrogen-bonding between the *distal*-amide moieties and then increased formation of a new intermolecular hydrogen-bonding based on the solvent.

Chemical shifts changes of *cone*-**4** and 1,3-*alternate*-**4** in $CDCl_3$ and DMSO-d_6 were shown in Fig. 1. The higher chemical shift change Ar*H* protons in 1,3-*alternate*-**4** ($\Delta\delta_{sol.}$ = + 0.07 ppm) than that of *cone*-**4** ($\Delta\delta_{sol.}$ = –0.02 ppm) may also be attributed by the conformation change of 1,3-*alternate*-**4** in DMSO-d_6. It was also found that in the case of *cone*-**4** the chemical shift of the methylene protons of OCH_2CONH_2 negligibly shifted to upper field ($\Delta\delta_{sol.}$ = + 0.01 ppm) in DMSO-d_6, whereas much larger upper field shift ($\Delta\delta_{sol.}$ = + 0.23 ppm) was observed in 1,3-*alternate*-**4**, which might be attributable to being to locate in the area of the ring current effect[28–30] arising from the two inverted calixarene benzene rings.

The calixarenes show concentration-independent hydroxyl stretching bands in the 3200 cm^{-1} region of the infrared spectrum and a signal at δ 9–10 ppm in the ^{1}H NMR spectrum, indicative of very strong intramolecular hydrogen bonding and the cyclic nature of calixarenes.[1–4] The IR (KBr) spectrum of *distal*-**3** shows the absorption for the hydroxyl stretching vibration around 3334 cm^{-1}. The ^{1}H NMR signal for hydroxyl group was observed at δ 8.43 ppm in $CDCl_3$. These observations suggest the intramolecular hydrogen bonding does exist in di-*O*-alkylated derivative *distal*-**3**. Furthermore, the previously noted upfield shift for the methylene protons in the CH_2CONH_2 in the ^{1}H NMR spectra of 1,3-*alternate*-**4** has not been observed (OCH_2CONH_2 methylene protons at δ 4.69 ppm). Therefore, the *distal*-**3** might adopt the *cone*-conformation due to the intramolecular hydrogen bonding between two hydroxy groups and alkoxy groups. Thus hydroxy groups and alkoxy groups of dialkoxytetrathiacalix[4]arenes have a tendency to orientate in the same direction and therefore favoured the adoption of the "cone" conformation.

Conclusions

An interesting result was obtained by introduction of carbamoylmethoxy groups into the hydroxy groups of tetrathiacalix[4]arene **1**. We have demonstrated for the first time that *O*-alkylation of the flexible macrocycle **1** with 2-bromoacetamide gave *cone*-5,11,17,23-tetra-*tert*-butyl-25,26,27,28-tetrakis(carbamoylmethoxy)-2,8,14,20-tetrathiacalix[4]arene *cone*-**4** and the corresponding 1,3-*alternate*-**4** conformer as well as the 1,3-disubstituted bis (carbamoylmethoxy)thiacalix[4]arene *distal*-**3**. The alkali metal cation can play an important role for the confomer distribution based on the template effect. An interesting intramolecular hydrogen bond network was observed in *cone*-**4** for the first time. Further studies on the inclusion properties of the tetrakis(carbamoylmethoxy)thiacalix[4]arenes are now in progress.

Experimental

All melting points are uncorrected. ^{1}H NMR spectra were recorded at 300 MHz on a Nippon Denshi JEOL FT-300 NMR spectrometer in deuteriochloroform with Me_4Si as an internal reference. IR spectra were measured as KBr pellets on a Nippon Denshi JIR-AQ2OM spectrometer. Mass spectra were obtained on a Nippon Denshi JMS-HX110A Ultrahigh Performance Mass Spectrometer at 75 eV using a direct-inlet system. Elemental analyses were performed by Yanaco MT-5.

Materials

5,11,17,23-Tetra-*tert*-butyl-2,8,14,20-tetrathiacalix[4]arene-25,26,27,28-tetraol **1** was prepared from *p*-*tert*-butylphenol according to the reported procedure.[9]

Distal-5,11,17,23-tetra-tert-butyl-25,27-bis(carbamoylmethoxy)-26,28-dihydroxy-2,8,14,20-tetrathiacalix[4]arene (*distal*-**3**): A mixture of **1** (760 mg, 1.05 mmol) and Na_2CO_3 (110 mg, 1.05 mmol) in dry acetone (10 cm^3) was heated at reflux for 1 h. Then 2-bromoacetamide [$BrCH_2CONH_2$] (**2**) (290 mg, 2.11 mmol) was added and the mixture heated at reflux for 48 h under argon. After cooling the reaction mixture to room temperature, it was filtered. The filtrate was concentrated and the residue was extracted with $CHCl_3$ (30 cm^3 × 2) and washed with 1M HCl (20 cm^3), water (40 cm^3 × 2), dried (Na_2SO_4). The filtrate was concentrated to give a yellow oil, which was then washed with MeOH to give the crude *distal*-**3** (702 mg, 80%) as a white solid. Recrystallisation from chloroform:MeOH (3 : 1) gave *distal*-**3** as colourless prisms, m.p. 181–183 °C; IR ν (KBr)/cm^{-1} 3467 (NH), 3334 (OH), 3187 (NH) and 1694 (CO); δ_H ($CDCl_3$) 1.09 (18H, s, *t*Bu), 1.27 (18H, s, *t*Bu), 4.69 (4H, s, OCH_2CO), 5.88 (2H, broad s, *NH*$_a$), 7.48 (4H, s, Ar*H*), 7.67 (4H, s, Ar*H*), 8.43 (2H, s, *OH*) and 8.55 (2H, s, *NH*$_b$); δ_H (DMSO-d_6–$CDCl_3$, 20:1) 0.84 (18H, s, *t*Bu), 1.28 (18H, s, *t*Bu), 4.88 (4H, s, OCH_2CO), 7.11 (4H, s, Ar*H*), 7.45 (2H, s, *NH*$_a$), 7.71 (4H, s, Ar*H*), 7.58 (2H, s, *NH*$_b$) and 8.68 (2H, s, *OH*); *m/z*: 834.29 (M^+). Found: C, 63.02; H, 6.49, N, 3.33. $C_{44}H_{54}N_2O_6S_4$ (835.17) requires C, 63.28; H, 6.52; N, 3.35%.

Preparation of cone-5,11,17,23-tetra-tert-butyl-25,26,27,28-tetrakis(carbamoyl-methoxy)-2,8,14,20-tetrathiacalix[4]arene (*cone*-**4**): A mixture of **1** (2.0 g, 2.76 mmol) and Na_2CO_3 (2.92 g, 27.6 mmol) in dry acetone (10 cm^3) was heated at reflux for 1 h. Then 2-bromoacetamide **2** (3.82 g, 27.6 mmol) was added and the mixture heated at reflux for 48 h under argon. After cooling the reaction

mixture to room temperature, it was filtered. The filtrate was concentrated and the residue was extracted with $CHCl_3$ (60 $cm^3 \times 2$) and washed with 1M HCl (40 cm^3), water (40 $cm^3 \times 2$), dried (Na_2SO_4). The filtrate was concentrated to give a yellow oil, which was then washed with MeOH (10 cm^3) to give the crude *cone*-**4** (2.1 g, 80%) as a white solid. Recrystallisation from chloroform–MeOH (3 : 1) gave *cone*-**4** as colourless prisms, m.p. 348–350 °C; IR ν (KBr)/cm^{-1} 3350, 3176 (NH) and 1652 (CO); δ_H ($CDCl_3$) 1.13 (36H, s, *t*Bu), 4.68 (8H, s, OCH_2CO), 7.43 (8H, s, Ar*H*), 7.69 (4H, broad s, NH_a) and 7.83 (4H, broad s, NH_b); δ_H (DMSO-d_6–$CDCl_3$, 20:1) 1.08 (36H, s, *t*Bu), 4.67 (8H, s, OCH_2CO), 7.37 (4H, broad s, NH_a), 7.45 (8H, s, Ar*H*) and 7.70 (4H, broad s, NH_b); *m/z*: 949.37 (M^+). Found: C, 60.62; H, 6.19, N, 5.77. $C_{48}H_{60}N_4O_8S_4$ (949.28) requires C, 60.73; H, 6.37; N, 5.90%.

The splitting pattern in ^{1}H NMR shows that the isolated compound is *cone*-**4**.

*O-Alkyltion of **1** with 2-bromoacetamide in the presence of NaH*: A mixture of **1** (400 mg, 0.55 mmol) and NaH (220 mg, 5.50 mmol, 60 wt%) in THF (40 cm^3) was heated at reflux for 1 h. Then 2-bromoacetamide (**2**) (758 mg, 5.50 mmol) was added and the mixture heated at reflux for 48 h under argon. After cooling the reaction mixture to room temperature, it was filtered. The filtrate was concentrated and the residue was extracted with $CHCl_3$ (60 $cm^3 \times 2$) and washed with 1M HCl (40 cm^3), water (40 $cm^3 \times 2$), dried (Na_2SO_4). The filtrate was concentrated to give a yellow oil, which was then washed with MeOH (10 cm^3) to give the starting compound **1** (390 mg, 98%) as a white solid.

Preparation of 1,3-alternate-5,11,17,23-tetra-tert-butyl-25,26,27,28-tetrakis(carbamoylmethoxy)-2,8,14,20-tetrathiacalix[4]arene (*1,3-alternate*-**4**): A mixture of **1** (400 mg, 0.55 mmol) and Cs_2CO_3 (1.80 g, 5.5 mmol) in dry acetone (40 cm^3) was heated at reflux for 1 h. Then $BrCH_2CONH_2$ (758 mg, 5.5 mmol) was added and the mixture heated at reflux for 48 h under argon. After cooling the reaction mixture to room temperature, it was filtered. The filtrate was concentrated and the residue was extracted with CH_2Cl_2 (40 $cm^3 \times 2$) and washed with 1M HCl (20 cm^3), water (20 $cm^3 \times 2$), dried (Na_2SO_4). The filtrate was concentrated to give a yellow oil, which was then distilled under reduced pressure to afford a crude product. The residue was washed with MeOH to give the crude 1,3-*alternate*-**4** (444 mg, 85%) as a white solid. Recrystallisation from $CHCl_3$: MeOH (3 : 1) gave 1,3-alternate-**4** as colourless prisms, m.p. 339–341 °C; IR ν (KBr)/cm^{-1} 3310, 3160 (NH) and 1666 (CO); δ_H ($CDCl_3$) 1.26 (36H, s, tBu), 4.50 (8H, s, OCH_2CO), 5.18 (4H, broad s, NH_a), 5.23 (4H, broad s, NH_b) and 7.40 (8H, s, ArH); δ_H (DMSO-d_6–$CDCl_3$, 20 : 1) 1.21 (36H, s, tBu), 4.27 (8H, s, OCH_2CO), 5.54 (4H, broad s, NH_a), 6.58 (4H, broad s, NH_b) and 7.33 (8H, s, Ar*H*); *m/z*: 949.28 (M^+). Found: C, 60.53; H, 6.09, N, 5.73. $C_{48}H_{60}N_4O_8S_4$ (949.28) requires C, 60.73; H, 6.37; N, 5.90%.

The splitting pattern in ^{1}H NMR shows that the isolated compound is 1,3-*alternate*-**4**.

Preparation of 4-tert-butyl-2,6-dimethyl(carbamoylmethoxy)benzene **6**: A mixture of 4-*tert*-butyl-2,6-dimethylphenol **5**[27] (400 mg, 2.25 mmol) and NaH (580 mg, 14.5 mmol, 60 wt%) in dry THF (20 cm^3) was heated at reflux for 1 h under N_2. Then a solution of bromoacetamide was added and the mixture heated at reflux for an additional 48 h. After cooling the reaction mixture to room temperature, it was acidified with 1 M HCl (10 cm^3) and extracted with CH_2Cl_2 (100 $cm^3 \times 2$). The combined extracts were washed with water (50 $cm^3 \times 2$), dried (Na_2SO_4) and condensed under reduced pressure to give a yellow oil. The residue was treated with MeOH (5 cm^3) to give the crude **6** (424 mg, 80%) as a white solid. Recrystallisation from $CHCl_3$:MeOH (3 : 1) gave **6** as colourless prisms; m.p. 201–203 °C; IR ν (KBr)/cm^{-1} 3306, 3173 (NH), 1666 (CO); δ_H ($CDCl_3$) 1.28 (9H, s, *t*Bu), 2.28 (6 H, s, Me), 4.32 (2 H, s, OCH_2CO), 5.54 (1 H, broad s, NH_a), 6.05 (1H, broad s, NH_b) and 7.02 (2H, s, Ar*H*); δ_H (DMSO-d_6–$CDCl_3$, 20:1) 1.24 (9 H, s, *t*Bu), 2.18 (6 H, s, Me), 4.09 (2 H, s, OCH_2CO), 7.02 (2H, s, Ar*H*), 7.10 (1 H, broad s, NH_a), 7.38 (1H, broad s, NH_b) and *m/z* 235 (M^+) (Found: C, 71.59; H, 8.78; N, 5.83. $C_{14}H_{21}NO_2$ (235.32) requires C, 71.46; H, 8.99; N, 5.95%.

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